BETT TTEB

Energy Conservation Considerations for the Warehousing and Light Industrial Building Category

A RESEARCH REPORT

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Sponsored by the
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The Buildings Energy Technology Transfer Program (BETT) of EMR has been created to assist building owners, users and practitioners active in the design, construction and operation of buildings in identifying technical obstacles to energy conservation. Through a nationwide network of research agencies and private sector consultants, BETT carries out research and development projects and provides the audiences mentioned above with technical reports, how-to manuals, training manuals, audio-visual aids and data bases to help them overcome these obstacles.

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ABSTRACT/RESUME

The Buildings Energy Technology Transfer program was initiated by Energy, Mines and Resources Canada in late 1981. The Building Engineering Group was chosen to develop and execute a comprehensive R, D and D program for energy conservation in the warehousing and light industrial category of buildings.

This report is a synthesis of some of the work done by the Building Engineering Group within the first phase of the program. An attempt has been made to:

- define and quantify the building category
- assess the magnitude and nature of the non-process energy consumed
- identify some conservation strategies and the potential savings involved

* * *

Energie, Mines et Ressources Canada a lancé à la fin de 1981 le Programme de transfert de la technologie de l'énergie dans les bâtiments. Le Building Engineering Group a été choisi pour élaborer et mettre à exécution un programme complet de recherche, de développement et de démonstrations en matière d'économie d'énergie dans les entrepôts et immeubles d'industrie légère.

Le présent rapport est une synthèse de certains travaux menés par le Building Engineering Group dans la première phase du programme. Il cherche:

- à définir et à quantifier cette catégorie d'immeubles;
- à évaluer la quantité et la nature de l'énergie non industrielle consommée dans ces immeubles;
- à déceler certaines stratégies et possibilitiés d'économie d'énergie; et

Le lecteur trouvera un sommaire en francois de ce rapport à la page i.

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Le Programme de transfert de la technologie de l'énergie dans les bâtiments a été lancé par Énergie, Mines et Ressources Canada vers la fin de 1981. Cinq organismes ont été choisis pour entreprendre un vaste programme pluriannuel de recherche et de développement dans le domaine des économies d'énergie; chacun devait orienter ses efforts sur une catégorie différente d'immeubles. Le Building Engineering Group (BEG) a été choisi pour élaborer et mettre à exécution un programme national pour la catégorie des entrepôts et immeubles d'industrie légère.

Le BEG a élaboré un plan de travail global comportant quatre phases interdépendantes:

1. Une phase initiale comportant l'élaboration de modalités d'exploitation, d'administration et de conseil; la préparation d'une série coordonnée de rapports sur la situation actuelle; la mise au point d'un profil statistique de la catégorie d'immeubles et le raffinement du plan de travail global.

2. Une phase de mise au point des ressources comportant: le logiciel pour l'analyse, la simulation et le calcul de charges énergétiques; une installation mobile de mesure et d'évaluation de rendement; une base de données complète et un dossier d'études ponctuelles.

3. Une phase d'investigation comportant la détermination et la solution de problèmes, lacunes ou questions précises.

4. Une phase de mise en oeuvre dont l'objectif principal est de réaliser une mesure sensible d'économies d'énergie dans les entrepôts et immeubles d'industrie légère.

Le présent rapport - le onzième - est une synthèse des travaux faits par le BEG ou au nom du BEG, dans la première phase de ce programme de recherche et de développement d'une durée de trois à quatre ans. Il traite de trois questions:

- la définition et la quantification de la catégorie des entrepôts et immeubles d'industrie légère. On catégorise les genres d'immeuble et définit l'immeuble-type de la catégorie; il est établi que la catégorie des entrepôts et immeubles d'industrie légère vient en deuxième lieu selon la superficie totale après la catégorie des immeubles résidentiels. Il y a au Canada plus de 66 000 immeubles de la catégorie dont 48 441 entrepôts et 17 792 immeubles d'industrie légère, ayant une superficie totale de plus de 98,5 millions de mètres carrés (c'est-à-dire plus d'un milliard de pieds carrés). Le parc s'accroît au rythme de 3 % à 4 % par année.

- La quantité et la nature de l'énergie non industrielle consommée par cette catégorie d'immeuble. La consommation totale d'énergie au Canada par la catégorie est d'au moins 115 millions de gigajoules par année et le coût s'élève à plus de 540 millions de dollars par année. L'Ontario et le Québec représentent environ 67 % de la consommation et la part de l'Ontario est presque deux fois celle du Québec. Il convient de relever que plus de 80 % de cette énergie proviennent du gaz naturel et que le pétrole ne représente que 5 ou 6 %. La climatisation et l'éclairage sont les principaux consommateurs mais dans certains immeubles d'industrie légère l'aération, c'est-à-dire l'air d'appoint, peut consommer plus d'énergie que l'éclairage. Les entrepôts réfrigérés et frigorifiques représentent une proportion importante (17 %) de l'énergie totale consommée par les entrepôts et immeubles d'industrie légère.

- Stratégies et possibilités d'économie d'énergie dans les entrepôts et immeubles d'industrie légère. Les trois étapes stratégiques sont notamment la décision d'engager des ressources, le choix des moyens et la mise en oeuvre. Quatre stratégies globales d'économie d'énergie sont offertes et un scénario relativement

prudent d'économie d'énergie est élaboré. Il est évident que sur une période de dix ans on pourrait économiser environ 55 millions de gigajoules d'énergie dans les entrepôts et immeubles d'industrie légère. En dollars de 1981, ces économies pourraient atteindre 240 millions.

1.1 Objective

The principal objective of this report is to synthesize the work done to date by the Building Engineering Group (BEG) under the Buildings Energy Technology Transfer (BETT) program*. Therefore this report provides a summary statement on the warehousing and light industrial building category that:

(i) defines and quantifies this building category

(ii) documents the nature and magnitude of the non-process energy consumed by this category of building

(iii) identifies some strategies and their potential for energy conservation.

1.2 Scope

This report is intended as a "stand-alone" document that synthesizes, complements and qualifies the work already completed by BEG in the first phase of the BETT program. By itself it is not intended to be either a comprehensive state-of-practice report or the definitive statement on the nature and needs of this building category. Our knowledge of this building cateogry is limited; certainly much of the statistical data requires qualification. Our understanding of the businesses and industries involved is even more limited, and it is anticipated that some of the ideas and conclusions in this report will need to be refined or revised.

The information contained in the ten BEG reports completed to date is not reproduced or summarized in this report (where necessary, relevant documents are referenced). This report has been kept as brief and to-the-point as possible; emphasis is

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* There were ten BEG reports completed at the time this report was written. The reports are referred to by the number from 1 to 10 assigned to them by BEG. All 10 reports are listed under References. It should be noted that reports 3, 8 and 10 are unpublished. The balance of the reports have been published in this BETT Research Report series.

placed on issues of overall significance rather than detail and qualification. The latter is needed, but priority must be given first to quantifying the primary issues involved. Accordingly, the ten individual reports may be regarded as appendices to this report, and collectively this body of work may be regarded as constituting a state-of-practice study of the warehouse and light industrial building (WLIB) category.

2.1 Categorization

In attempting to define and categorize buildings, probably the principal determinants are general purpose (e.g., residential, commercial, industrial or other sectors) and specific use (e.g., rental housing, hotel accommodation, hospital, education, storage, etc.). Secondary parameters would be largely scale-related, e.g., single or multiple; low, medium or high rise, etc.

In Figure 2.1 an attempt has been made to identify and categorize the universe of all buildings. It is evident from Figure 2.1 that both the warehousing and the light industrial components of this building category extend across more than one building sector. A unique feature of the type of building that constitutes this category is that it is common to many businesses, industries or services, both public and private. In fact, the ubiquity of WLIBs and the multiplicity of purposes they serve make it difficult to define with much precision the limits of this particular category. It is therefore useful to identify and define a representative warehouse or light industrial building, and thus, by inference, address all those similar buildings that constitute the major proportion of this building category.

2.2 The Basic Warehouse or Light Industrial Building

Photographs of some typical buildings are provided. Any of these buildings can be categorized in terms of its enclosure system, service systems and the interior environment. Thus the physical features that characterize a representative WLIB may be grouped as follows.

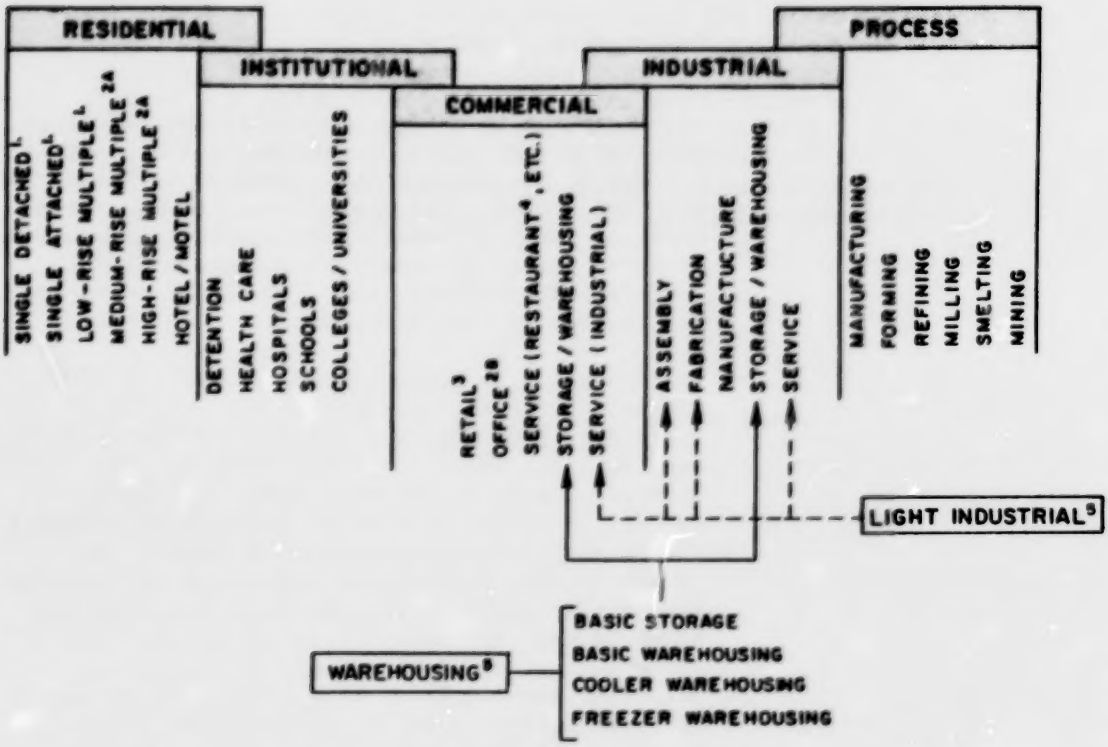
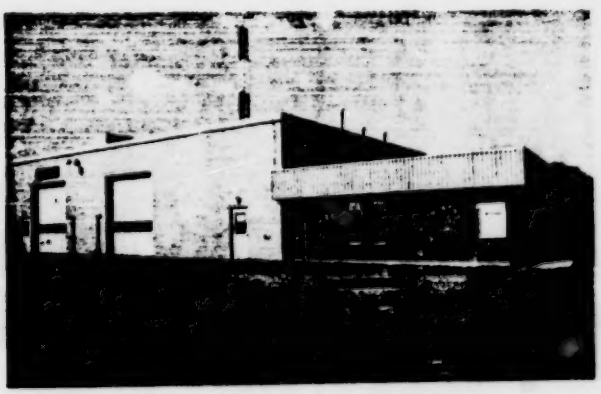
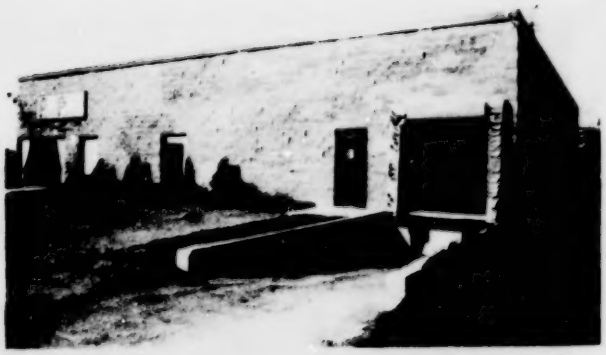


FIGURE 2.1: The Universe of Buildings in the Warehousing and Light Industrial Building Category



TYPICAL LIGHT INDUSTRIAL BUILDINGS



TYPICAL WAREHOUSE BUILDINGS

2.2.1. Enclosure

Typically a WLIB is rectangular in shape, or it consists of a combination of rectangular modules. Essentially single-storeyed, with vertical sides and a flat or flattish roof, the building is usually designed to provide a large, unobstructed volume of space. Clear heights of 10 metres or more are not uncommon. The choice of structural system usually reflects a compromise between minimum obstruction and minimum first cost. The floor system is usually a concrete slab-on-grade. With the exception of a small portion of the building that may be used as offices, the walls are usually windowless. Shipping doors are usually concentrated on one side of the building.

Normally the enclosure is weather-sensitive in that neither process nor usage significantly affect the thermal performance of the building, i.e., WLIB's are essentially thermally independent of process, people and traffic loads. There are, however, two subcategories of the WLIB category that are process-dependent: cooled and refrigerated warehousing.

The above description is by no means all inclusive and many buildings that fall into the WLIB category are more than one storey in height, have pitched roofs or have many windows. This is particularly true of older, pre-1950, industrial buildings. Brief histories of the development of the modern warehouse and light industrial building are provided in Reports #8 and #9. Report #8 was also intended as a review of the state of practice for roof and wall systems for WLIBs.

2.2.2. Service Systems

In general non-process energy requirements predominate and the related services are:

- space heating
- lighting
- hot water heating.

In Canada air conditioning is not commonly provided in buildings in this category. Cooling and refrigeration are classified as process loads. Furthermore, most service systems are relatively simple e.g., unitized, roof mounted or suspended, heating systems.

A comprehensive review of mechanical and electrical systems is provided in Report #10.

2.2.3. The Interior Environment

The conditions that exist within WLIBs vary greatly, but in many instances the following prevail:

- Minimal or intermittent illumination is required, even in a windowless building.

- Significant fluctuations on both sides of the desired level for temperature and relative humidity can and do occur. For example, with certain kinds of dry storage, the only requirement might be that the indoor temperature stay above freezing.

- Air quality is not usually an issue. In only a relatively small proportion of light industrial buildings is exhaust ventilation a problem. This issue is assessed in Report #2, as it is appreciated that forced ventilation can have a significant impact on energy costs.

- Air pressure, air leakage, infiltration, and stratification are all interdependent factors that are of varying importance. Report #7 deals with some of these issues.

2.3 The Magnitude, Composition and Distribution of WLIBs.

The first task undertaken by BEG in the BETT program was to gather and review all accessible data on warehousing and light industrial buildings in order to develop a statistical profile of this category. The figures that follow are taken from Report #1, which is the first phase in the longer-term task to develop a reliable and comprehensive profile of WLIBs in Canada. In general these figures should be regarded as estimates rather than facts. Reference should be made to the report for details of sources of data and estimation procedures.

2.3.1. Warehouses

Table 2.1 provides some indication of the amount of warehousing in Canada and its distribution by province and year of construction. Table 2.2 quantifies the type of storage involved. These two tables provide, for the first time, a profile of the Canadian stock of warehouses. Information as to ownership, quality of stock, materials of construction, etc., is still needed, but Tables 2.1 and 2.2 do permit the following conclusions:

(i) It is estimated that there are some 48,000 warehouses with a total of 60.3 million square metres (649 million square feet).

(ii) More than one-third of all warehouse space is concentrated in Ontario; some 56.6 per cent of all warehousing is in the provinces of Ontario and Quebec.

(iii) Over 81 per cent of warehousing is dry storage. About 6 per cent is cooler storage while twice as much is refrigerated. A significant proportion (nearly 20 per cent) of the refrigerated storage space is in British Columbia.

(iv) On the basis of warehouse space, it would appear that, initially, priority should be given to dry storage buildings and the stock of dry storage warehousing in the provinces of Ontario and Quebec.

(v) New stock is added at a rate of between 3 and 4 per cent per year.

TABLE 2.1 : DISTRIBUTION BY REGION AND AGE OF THE STOCK OF WAREHOUSE BUILDINGS IN CANADA [1]

PROVINCE	PRE '56 1000 m²	1956-73 1000 m²	1974-78 1000 m²	1979-81 1000 m²	TOTAL 1000 m²
NOVA SCOTIA	416	491	226	192	1,325
NEW BRUNSWICK	626	532	298	123	1,579
NFLD & PEI	465	283	107	103	958
QUEBEC	6,047	4,293	1,953	737	13,030
ONTARIO	9,349	6,918	2,611	2,154	21,032
MANITOBA	1,157	1,099	478	324	3,058
SASKATCHEWAN	1,204	807	277	433	2,721
ALBERTA	1,960	1,940	1,933	2,567	8,400
B.C.	3,041	2,645	1,290	1,176	8,152
CANADA	24,265 (40.3%)	19,008 (31.5%)	9,173 (15.2%)	7,809 (13.0%)	60,255 (100.0%)
					48,441 BUILDINGS

60,255,000 m² = 649 million square feet

TABLE 2.2 : DISTRIBUTION AND TYPE OF WAREHOUSING SPACE IN CANADA [1]

REGION	TYPE OF STORAGE AREA			
	DRY STORAGE	COOLER STORAGE	FREEZER STORAGE	TOTAL
ATLANTIC REGION	6.0%	3.5%	10.5%	6.4%
QUEBEC	22.5%	23.7%	15.1%	21.6%
ONTARIO	34.2%	55.8%	30.0%	35.0%
MANITOBA	4.3%	4.9%	10.1%	5.1%
SASKATCHEWAN	4.6%	0.2%	5.8%	4.5%
ALBERTA	15.6%	1.2%	9.0%	13.9%
B.C.	12.8%	10.7%	19.5%	13.5%
	100%	100%	100%	100%
CANADA	529.10⁴ ft² 49.2 10⁴ m² 81.6%	39.10⁴ ft² 3.6 10⁴ m² 6.0%	81.10⁴ ft² 7.5 10⁴ m² 12.4%	649.10⁴ ft² 60.3 10⁴ m² 100%

2.3.2 Light Industrial Buildings

A limited profile of the magnitude and distribution of light industrial buildings is provided in Table 2.3. One qualification that needs to be stated is that the amount of rented floor space has been estimated on the basis that 70 per cent of all light industrial space is corporately owned and used by the owner. Data on corporately owned space would appear to be reliable. Although the seventy-thirty per cent breakdown is questionable, no alternative figure is available. Thus, the totals in Table 2.3 represent lower bounds on the stock of light industrial buildings.

Accordingly, there are at least 17,792 buildings with a total area of at least 38 million square metres (412 million square feet). Nearly 80 percent of the stock is in Ontario (53%) and Quebec (25%). New stock is added at the rate of about 3 per cent per year.

2.3.3 WLIB's

This building category includes buildings that are used for warehousing and/or light industrial purposes. The summary contained in Table 2.4 indicates that there are some 66,000 buildings involved with a total area of about 100 million square metres or well over 1 billion square feet.

TABLE 2.3 : FLOOR AREA OF LIGHT INDUSTRIAL BUILDINGS IN CANADA [1]

REGION	CORPORATELY OWNED FLOOR SPACE IN 1000 m²					UNIVERSE OF OWNED & RENTED TOTAL 1000 m²
	Pre '61	1961-73	1974-78	1979-81	TOTAL	
QUEBEC	3,024 (30%)	2,417 (24%)	833 (2%)	404 (10%)	6,678 (70%)	9,537 (25%)
ONTARIO	6,189 (62%)	5,257 (51%)	1,504 (38%)	1,130 (44%)	14,080 (53%)	20,111 (53%)
CANADA	10,032	10,228	3,945	2,590	26,795	38,278
	37%	38%	15%	10%	100%	
						(17,792 - BUILDINGS)

TABLE 2.4 : MAGNITUDE OF THE WAREHOUSE AND LIGHT INDUSTRIAL BUILDING CATEGORY IN CANADA

TYPE	FLOOR AREA		NUMBER OF BUILDINGS
	SQ. M. 10^6	SQ. FT. 10^6	
WAREHOUSING	60.257	648.592	48,441
LIGHT IND. BLDGS.	38.278	412.008	17,792
TOTAL WLIB	98.5	1,060.6	66,233

3.1 Energy Consumption in Warehouse Buildings

Given the lack of alternatives, estimates of total energy consumption have to be calculated by multiplying total floor areas by representative annual energy consumption rates, that is, energy densities. The magnitude and composition of these energy density values are therefore significant and need to be considered in some detail.

Some data on energy density is provided in Table 3.1. Conservation priorities are as follows:

- space conditioning, principally heating, which consumes the most energy
- lighting, which is second in order of significance
- non-process hot water heating, which is a relatively insignificant contributor to energy usage.

It should be evident that both the magnitude and make-up of these values are highly variable. The first point that needs to be made concerns conservation priorities. Representative values for energy density (energy per unit area per year) range from 0.85 to 1.58 Gigajoules per square metre per year (GJ/m^2/year). Energy density values will vary with use (commercial or industrial, nature of goods being stored, etc.) and type of storage (dry, cooled or refrigerated). For example, representative values of 1.16, 2.13 and 3.29 GJ/m^2/year have been suggested for dry, cooled and refrigerated storage respectively [13]. However, the range of actual values is considerable. For example, one reference recommends a representative value of 1.42 GJ/m^2 for various warehouses exhibiting a range of values from a low of 0.57 GJ/m^2 to a high of 17.05 GJ/m^2. Clearly the value of 1.42 is based on a sample that includes refrigerated warehousing.

In BEG Report #1 a representative value of 1.162 GJ/m^2 was used to compute the energy consumption figures listed in Table 3.2. Irrespective of the single value chosen, the relative proportion consumed in each province is not likely to vary, but clearly the totals are very dependent on the energy density. For example, if the value 1.42 GJ/m^2,

ENERGY USE (NON-PROCESS)	DRY STORAGE WAREHOUSE [5]			REPRESENTATIVE DRY STORAGE WAREHOUSE [1]		
	GJ/m ^{2}	KWH/f^2	%	GJ/m^2	KWH/f^2	%
SPACE CONDITIONING (HVAC)	1.345	34.7	85.1	0.62	16.0	53.3
LIGHTING	0.179	4.6	11.3	0.25	6.5	21.7
HOT WATER HEATING	-	-	-	0.02	0.5	1.7
PRODUCTION/AUXILIARY	0.049	1.3	3.1	0.27	7.0	23.3
MISCELLANEOUS (OFFICE, ETC.)	0.008	0.2	0.5	-	-	-
TOTAL	1.581	40.8	100.0	1.16	30.0	100.0

NOTE:

1 : An average value of 36.6 KWH/f^2/Year or 1.42 GJ/m^2/Year and a range of 14.7 to 440 KWH/f^2/Year or 0.57 to 17.05 GJ/m^2/Year is given in Reference [11]

2 : Based on U.S. data for Region 1 (less than 2,000 cooling degree days, more than 7,000 heating degree days) the mean annual warehouse energy density is 22 KWH/f^2 or 0.85 GJ/m^2.

3 : Representative values of 55 KWH/f^2 or 2.13 GJ/m^2 and 85 KWH/f^2 or 3.29 GJ/m^2 have been suggested for cooled and refrigerated warehouses respectively. Reference [12].

TABLE 3.1 : ENERGY CONSUMPTION IN WAREHOUSES

PROVINCE	ENERGY CONSUMED	
	PJ	%
NOVA SCOTIA	1.540	2.2
NEW BRUNSWICK	1.836	2.6
NFLD. & P.E.I.	1.114	1.6
QUEBEC	15.147	21.6
ONTARIO	24.450	35.0
MANITOBA	3.555	5.1
SASKATCHEWAN	3.163	4.5
ALBERTA	9.765	13.9
B.C.	9.477	13.5
CANADA	70.047	100.0

TABLE 3.2 : ESTIMATES OF ENERGY CONSUMPTION IN CANADIAN WAREHOUSE BUILDINGS (BASED ON ENERGY DENSITY OF 1.162 GJ/m²).

TYPE OF WAREHOUSING	STORAGE AREA $m^2 \times 10^6$	ENERGY DENSITY GJ/m^2	ENERGY CONSUMED	
			PJ or $GJ \times 10^6$	%
DRY STORAGE	49.2	1.16	57.1	63.8
COOLER STORAGE	3.6	2.13	7.7	8.6
FREEZER STORAGE	7.5	3.29	24.7	27.7
TOTAL	60.3		89.5	100.1

TABLE 3.3 : ESTIMATES OF ENERGY CONSUMPTION IN CANADIAN WAREHOUSE BUILDINGS (BASED ON THE ENERGY DENSITIES SHOWN).

which incorporates refrigerated storage, were to be used, then consumption values would be some 20 per cent greater. Another, possibly more logical, method of arriving at a consumption total would be to use the approach shown in Table 3.3. This approach gives a total energy consumption for Canadian warehousing of 89.5 PJ, some 28 per cent greater than that given in Report #1. This table also indicates that whereas dry storage accounts for about two thirds of the energy consumed, nearly 28 per cent (25 PJ) is required for refrigerated warehousing. Therefore, although dry storage must initially be given priority, attention must also be focused on the potential for energy conservation in refrigerated warehousing.

In addition to knowing how much energy is consumed and what it is used for, it is also necessary to know what fuels are involved. Table 3.4 shows that more than 80 per cent of the energy is supplied by gas, while electricity provides more than 12 per cent. It follows that only in Atlantic Canada is oil consumption likely to be directly affected by conserving energy in warehouse buildings. This is a not unimportant conclusion: one that might have a bearing on the time scale and priority for effecting conservation in warehouse buildings.

3.2 Energy Conservation in Light Industrial Buildings

The reason for combining warehouse buildings and light industrial buildings in the same category is that, in general, the types of building involved are very similar. Similar types of building are also used in sectors other than the commercial and industrial sectors, and it must be acknowledged that the building subcategory labelled warehousing does extend across a number of building sectors. On the other hand, the term light industrial buildings applies only to non-warehouse buildings in the so-called light industries. The term light industry therefore needs to be defined. Consideration of energy consumption is one method for prescribing light industrial buildings.

TABLE 3.4 : TYPES OF HEATING FUELS USED FOR NON-PROCESS HEATING IN CANADIAN WAREHOUSING [1]
(Based on Warehousing constructed between 1974 and 1981)

UNIT	PERCENTAGE DISTRIBUTION BY TYPE OF HEATING FUEL		
	GAS	OIL	ELECTRICITY
BUILDINGS	71.8	8.7	19.5
FLOOR AREA	82.3	5.3	12.4

Consider Table 3.5 which lists energy-related data for 10 major industrial groups each identified by their Standard Industrial Code (SIC) number. Each of these industries consumes more non-process energy than process energy. In this report and Report #1, this criterion has been the basis for identifying a "light" industry or the "light" component of an industry group. Of course a more restrictive criterion could be used; for example, a value of 2 for the non-process to process energy ratio would eliminate the leather and machinery industry groups.

Table 3.5 shows that the total amount of non-process energy consumed by light industrial buildings is 45.6 PJ (12.7 million MWH). This is 2.6 times the amount of process energy consumed by these industry groups.

The information provided in Table 3.5 also indicates that non-process energy use is composed of:

(i) space heating, which only in the clothing and light manufacturing component of the textile industry, is the largest consumer of energy

(ii) make-up air; which in most cases requires the most energy

(iii) lighting, which ranks as third but clearly a significant third, especially in the clothing industry (19.4%), printing and publishing (19.4%) and electrical products (17.2%) industry groups.

In light industrial buildings the provision of make-up air consumes considerable quantities of energy. The provision of make-up air and space heating are not unrelated and it is evident that, insofar as service systems and the interior environment are concerned, warehouses and light industrial buildings are somewhat dissimilar. These conclusions are reinforced by Table 3.6 which provides a provincial breakdown of energy consumption. It is significant that Ontario alone consumes more than 57 per cent of the total non-process light industrial building energy. Between them, Quebec and Ontario account for about 85 per cent of this energy. On a provincial basis, make-up air would appear on average to account for 54 per cent of the non-process energy consumed.

TABLE 3.5 : ENERGY CONSUMPTION FOR NON-PROCESS VERSUS PROCESS USES IN LIGHT INDUSTRIES FOR 1978 [1]

LIGHT INDUSTRIES		NON-PROCESS ENERGY USES					PROCESS USE	RATIO NON-PROCESS
SIC CODES	MAJOR GROUPS	SPACE HEATING %	LIGHTING %	MAKE-UP AIR %	TOTAL PJ	TOTAL % of Total	PJ	PROCESS
04	LEATHER	50.0	10.0	40.0	1.1010	2.41	0.9689	1.1
05	TEXTILE*	57.5	4.1	38.4	3.1964	7.01	0.2189	14.6
06	KNITTING	31.5	8.2	60.3	2.0951	4.60	0.3444	6.1
07	CLOTHING	51.6	19.4	29.0	1.5816	3.47	0.2041	7.7
08	WOOD*	37.8	10.8	51.4	3.1577	6.93	1.5362	2.1
09	FURNITURE & FIXTURES	19.3	12.3	68.4	2.6116	5.73	1.1454	2.3
11	PRINTING, PUBLISHING	22.2	19.4	58.4	4.2725	9.37	0.4747	9.0
13	METAL FABRICATING*	28.6	10.7	60.7	6.7781	14.87	2.6629	2.5
14	MACHINERY	35.6	6.7	57.7	6.2941	13.80	5.0353	1.2
16	ELECTRICAL PRODUCTS	23.4	17.2	59.4	9.9194	21.75	3.4098	2.9
20	MISCELLANEOUS	42.4	13.6	44.0	4.5856	10.06	1.4591	3.1
ALL LIGHT INDUSTRIES (PJ)		14.9589	5.6887	24.9455	45.5931	100	17.4597	2.6

* The consumption of all energy-intensive industries in these major groups has been excluded so that textile, wood, and metal fabricating represent only the light manufacturing industries within each major group.

TABLE 3.6 : BREAKDOWN BY PROVINCE OF NON-PROCESS ENERGY CONSUMPTION IN LIGHT INDUSTRIAL BUILDINGS [1]

PROVINCES	SPACE HEATING %	LIGHTING %	MAKE-UP AIR** %	TOTAL PJ	TOTAL % of Total
NOVA SCOTIA	32.9	12.6	54.5	0.2856	0.63
NEW BRUNSWICK	32.0	11.8	56.2	0.3241	0.72
NEWFOUNDLAND	36.6	10.9	52.5	0.1376	0.30
PEI	37.4	14.3	48.3	0.0342	0.08
QUEBEC	34.3	12.4	53.3	12.5568	27.83
ONTARIO	32.1	12.5	55.4	25.7754	57.13
MANITOBA	32.1	12.9	55.0	1.3378	2.97
SASKATCHEWAN	32.3	12.2	55.5	0.4730	1.05
ALBERTA	31.0	12.0	57.0	1.4498	3.21
BRITISH COLUMBIA	34.3	11.6	54.1	2.7436	6.08
TOTAL OF PROVINCES* (PJ)	14.8079	5.5894	24.7206	45.1179	100.0

* Differs from total for Canada because of residual quantities have not been allocated to provinces and energy consumed by tobacco industries is an aggregate quantity not divisible by the end use.

** Primarily concerned with replacing air contaminated with dust, chemicals, etc., with cleaned and heated air.

Table 3.7 indicates the type and amount of fuel used in each light industry. In order of priority, natural gas, electricity, oil and gasoline each provide a significant proportion of the energy used. As is the case with warehouses, energy conservation in light industrial buildings will not have any significant or direct effect on the national consumption of oil.

3.3 Energy Consumption in WLIBs

Figures for energy consumption in the WLIB category are summarized in Table 3.8. The values used are thought to be on the low side by as much as 28 per cent. The provincial distribution of WLIB energy consumption is shown in Figure 3.1.

Table 3.9 is an attempt to express the annual energy consumption in WLIBs in monetary terms. Clearly annual fuel costs are currently well in excess of one-half billion dollars.

TABLE 3.7 : PERCENTAGE DISTRIBUTION BY FUEL TYPE OF ENERGY CONSUMED IN VARIOUS LIGHT INDUSTRIES [1]

LIGHT INDUSTRIES		FUEL TYPES (%)						
SIC CODES	MAJOR GROUPS	NATURAL GAS	ELECTRICITY	FUEL OIL	GASOLINE	DIESEL OIL	LPG	TOTAL**
04	LEATHER	49.5	20.6	24.3	2.3	0.7	0.5	97.9
05	TEXTILE*	28.1	18.8	45.3	3.2	0.2	4.3	99.9
06	KNITTING	33.3	26.7	35.8	1.4	1.0	0.8	99.0
07	CLOTHING	25.6	38.9	19.2	13.0	0.4	1.7	98.8
08	WOOD*	45.2	20.7	18.5	9.0	3.2	1.9	98.5
09	FURNITURE & FIXTURES	46.1	24.1	18.7	6.0	2.3	1.5	98.7
11	PRINTING, PUBLISHING	38.0	34.6	13.9	11.9	0.2	0.2	98.8
13	METAL FABRICATING*	53.2	18.7	14.1	8.4	2.5	1.9	98.8
14	MACHINERY	55.3	22.7	12.8	4.9	1.0	1.9	98.6
16	ELECTRICAL PRODUCTS	49.1	30.3	16.0	1.5	0.3	2.3	99.5
20	MISCELLANEOUS	41.5	25.0	24.1	6.9	0.3	1.9	99.7

* The consumption of heavy industries within these major groups has been excluded.

** Other Fuels are kerosene, coal and coke.

TABLE 3.8 : ENERGY CONSUMPTION IN THE WAREHOUSE AND LIGHT INDUSTRIAL BUILDING CATEGORY IN CANADA

TYPE	NON PROCESS ENERGY CONSUMPTION		
	PJ ($GJ \times 10^6$)	MWH x 10^6 ($KWH \times 10^9$)	QUAD ($BTU's \times 10^{15}$)
WAREHOUSING	70.05	19.46	.066
LIGHT IND. BLDGS.	45.59	12.66	.043
TOTAL WLIB	115	32.1	.109

FIGURE 3.1 : SUM OF NON-PROCESS ENERGY CONSUMPTION OF WAREHOUSE AND LIGHT INDUSTRIAL BUILDINGS [1]

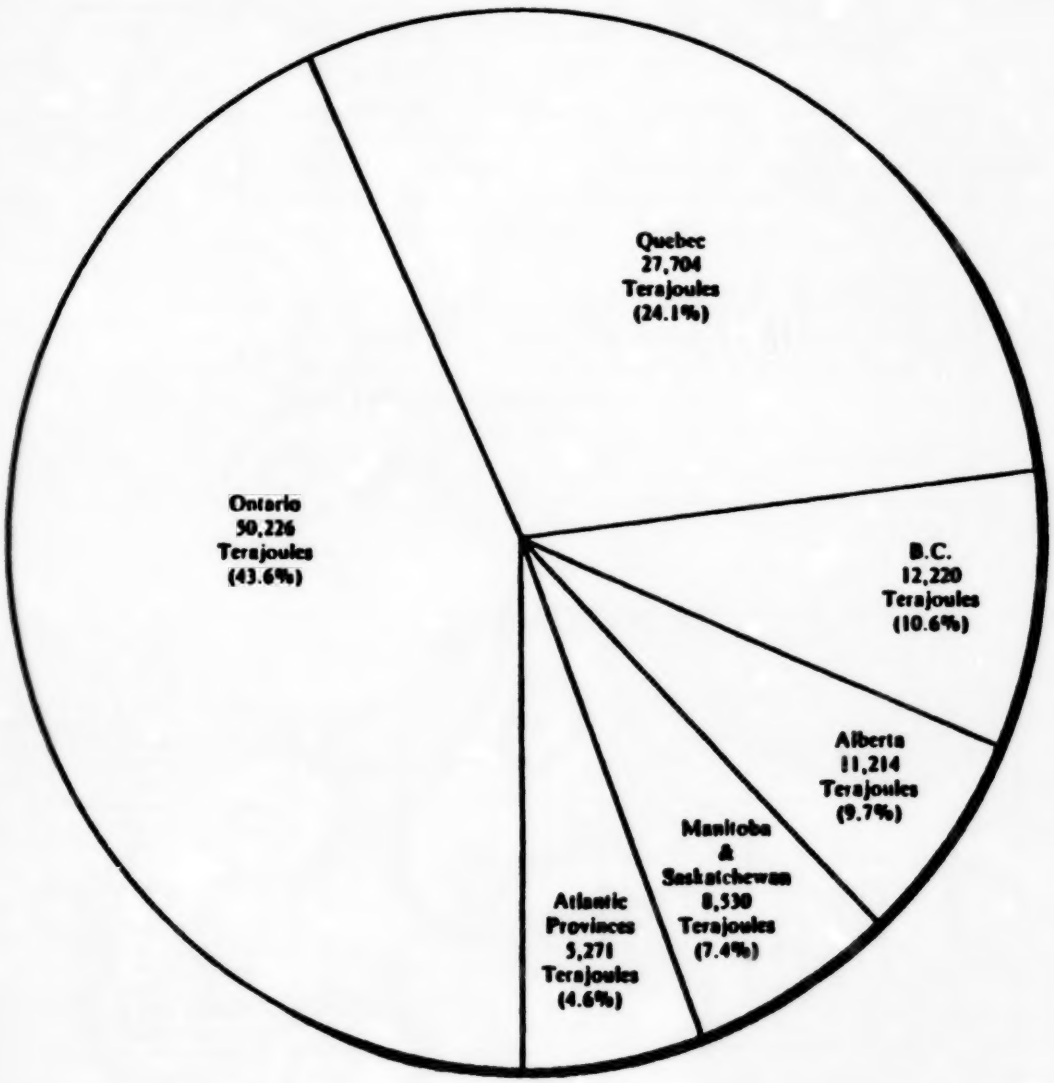


TABLE 3.9 : APPROXIMATE COST OF ENERGY CONSUMED PER YEAR BY THE WLIB CATEGORY

	ENERGY USED GJ x 10^6	TYPE OF FUEL	PROPORTION %	FUEL COST* $/GJ	APPROX. ENERGY x10^6$
WAREHOUSE (STORAGE) BUILDINGS	70.05	GAS	82.3	3.25	187.4
		OIL	5.3	7.50	27.8
		ELEC.	12.4	8.30	72.1
		ALL			287.3
LIGHT INDUSTRIAL BUILDINGS	45.59	GAS	50.0	3.25	74.1
		OIL	25.0	7.50	84.5
		ELEC.	25.0	8.30	94.6
		ALL			253.2
WLIBs	115.64				$540.5 x$10^6$

* APPROXIMATE CENTRAL CANADA COSTS.

4.1 Steps

In 1981 some 1.1 billion dollars of new warehousing (+$700 million) and light industrial (+$400 million) space was built in Canada. In the same year, the total stock of warehouse and light industrial buildings consumed energy costing well in excess of 0.5 billion dollars. Some 20 Petajoules of electricity, more than 70,000 million cubic feet of natural gas and 2.5 million barrels of oil, were used up for non-process purposes. There is evidently room for some conservation.

Irrespective of whether the entire stock of WLIBs or a single building is involved, the same three interdependent steps have to be taken in order to effect any saving, namely:

1. A decision or commitment to do so has to be made.

2. The wherewithal or means to undertake these conservation measures must be obtained or provided.

3. The conservation measures have, in fact, to be implemented.

It is perhaps unnecessary to point out that these steps are sequential, and only one sequence is possible. It is, however, necessary to point out that the order in which these steps are listed is, to some extent, indicative of:

(i) the degree of difficulty involved in effecting each step, and

(ii) priorities when devising a conservation strategy.

4.1.1 Decision

Any decision to undertake conservation will have to be taken in a climate of uncertainty, it being difficult to quantffy either cost or benefit- especially in the medium or longer term. This

decision will be essentially an economic decision, but it must be made within a context that is political and commercial where energy, as such, may have little or no priority for the individual building owner or tenant.

Any building may have:-

- the same owner, operator and user
- the same owner and operator, but a different user or users
- a different owner, but the same operator and user, or
- a different owner, operator and user or users.

Each of these combinations will affect any decision to be made, as the perception of cost, benefit and time frame will vary. Under prevailing economic conditions energy conservation is probably a low priority issue especially for a building owner. At the present time it would appear that for WLIBs there is little, if any, perceived advantage in conserving energy from the owner's and, especially from the individual tenant's, perspective. The governments perspective is, of course, different, and collectively the total amount of energy that could be conserved is significant. It follows that some sort of government action such as regulation, incentives, tax measures or concessions, may be deemed necessary in order to influence this initial, and crucial, decision-making step.

4.1.2 Means

The means to undertake conservation measures involves money and personnel. Both are critical but especially the latter, since any energy management system or conservation program is heavily dependent upon the competence and co-operation of the people involved. For example, good housekeeping alone (i.e., good management) can have a significant impact on energy costs.

For an existing building this step is often solely an in-house or company concern in that the influence of outside agencies, e.g., government, consultants, higher levels of management, need not be significant.

4.1.3 Implementation

In many respects this step is the simplest to address: by the time this stage is reached, the basic economic, political and corporate boundaries of the problem have been defined, and this step is reduced largely to technological and managerial issues. Technically, enough is already known to effect significant levels of conservation in both new and existing buildings. The success of implementation and its continued effectiveness is largely dependent on the quality of management involved.

4.2 Conservation Strategies

Variables such as age, materials of construction, weather, ownership, use, fuel type, fuel cost, security of fuel supply, etc., all have an influence on any conservation decision. It could be said that each and every building is unique and that there are as many optimal energy conservation strategies as there are buildings. Nonetheless, it is proposed that all conservation strategies can be categorized as one of four possible options and that each of these options must incorporate the three steps listed earlier.

In Table 4.1 this generalized hierarchy of conservation strategies is illustrated. The four pages that follow describe the general nature of each strategy. An attempt is made to identify and qualify the various influential factors and participants in Table 4.1.

In each strategy the emphasis is on the nature of, and the maker of, the basic decision to conserve or not. In each case a potential saving per building is indicated; these are consensus values arising from the work done to date by BEG. Based on 100 per cent implementation, the hypothetical annual savings in energy in 1981 dollars have been estimated for each strategy.

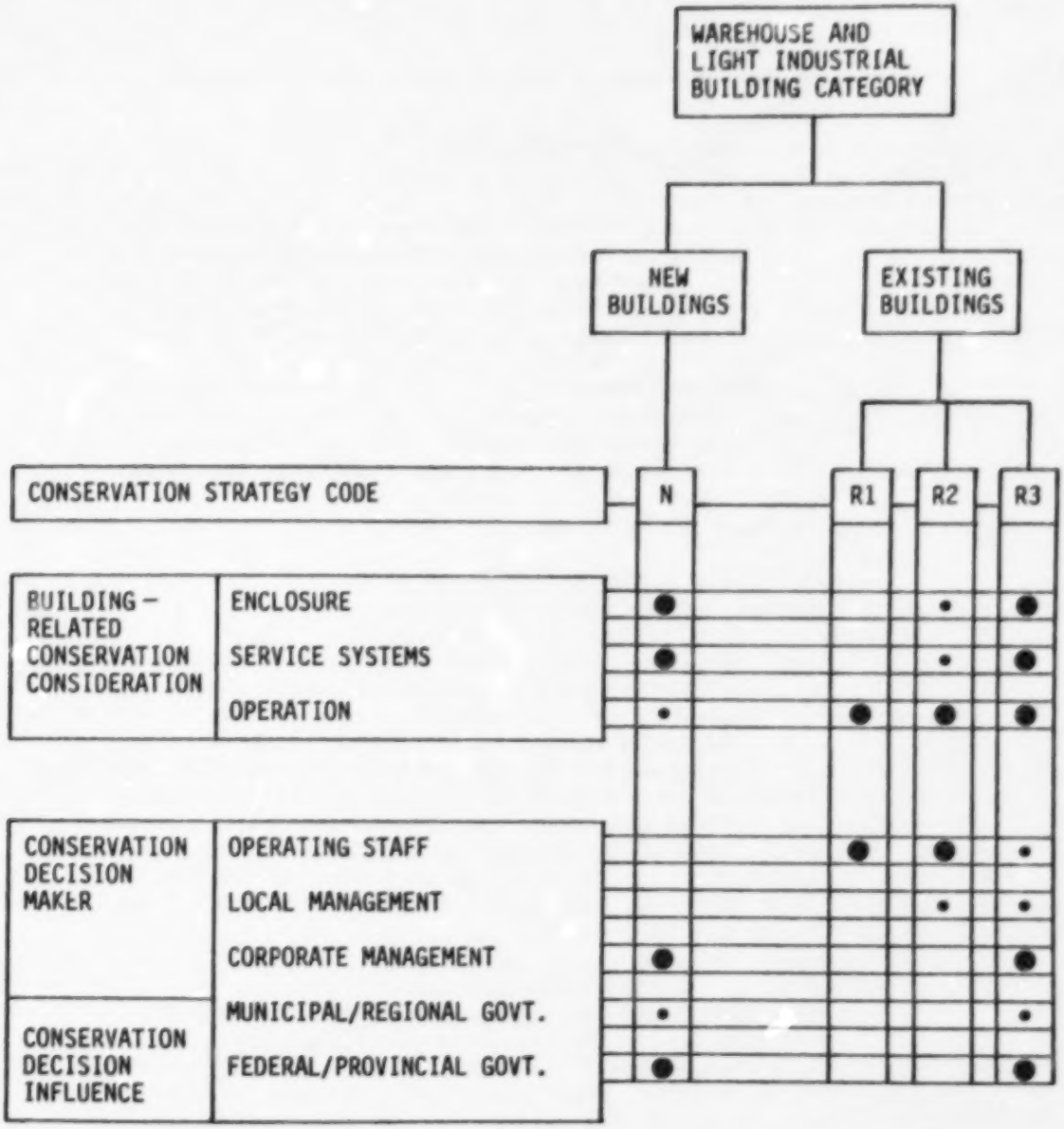


TABLE 4.1 : ENERGY CONSERVATION CONSIDERATIONS FOR WAREHOUSES AND LIGHT INDUSTRIAL BUILDINGS

● PRINCIPAL/PRIMARY
• SECONDARY/COMPLEMENTARY
☐ A BLANK INDICATES MINIMAL IMPORTANCE

} RELATIVE LEVEL OF SIGNIFICANCE

NOTE: THIS TABLE TO BE READ IN CONJUNCTION WITH pp 28, 29, 30 & 31.

CONSERVATION STRATEGY R1 - BETTER HOUSEKEEPING

REQUIREMENT

The total cost of all conservation measures is absorbed within the current annual operating and maintenance budget and can continue to be absorbed without budgetary perturbation.

MEASURES

Reduction of air leakage/infiltration by means of weatherstripping, caulking, etc., and better control of the operation of all openings in the enclosure, especially shipping doors. Improved maintenance procedures, e.g., temperature levels, servicing of equipment, etc. Better operating procedures for lighting. Improved work habits on the part of personnel.

POTENTIAL SAVINGS

A minimum saving of 5 per cent per year could be expected. An average saving of 5 per cent per building per year each year is equivalent to a national saving of more than $25,000,000 per year each year.

COMMENT

The strategy presumes that the roney saved by this conservation strategy would not be needed to directly pay for the conservation measures, and the primary incentive to reduce energy costs is to control or even decrease operating costs. Thus, the authority, incentive, and prerogative for action are operational, and the ownership of the building is not an issue.

CONSERVATION STRATEGY R2 - LOW-LEVEL ENERGY CONSERVATION RETROFIT

REQUIREMENT

The total cost of the conservation measures is absorbed within the current annual operating and maintenance budget, but the nature and extent of these costs may involve the phasing of conservation measures, the re-allocation of funds, and the use of energy savings to finance some or most of the retrofit.

MEASURES

In addition to those measures in Strategy R1, this could involve the provision of insulation, the sealing (by means of urethane foam, for example) of major cracks (at the wall-roof interface, for example), the installation of set-back thermostats, adjustments to the lighting, etc. No significant capital expenditures are envisaged.

POTENTIAL SAVINGS

A minimum of 15 per cent per year. A 15 per cent reduction in WLIB energy consumption represents a national saving of more than $75,000,000 per year.

COMMENT

On average, warehouses and light industrial buildings are about 4,000 m^2 in area. An energy saving of 15 per cent will represent about .2 GJ/m^2/year/building. This would produce a representative annual saving of about $3,200 (.2 x 4,000 x $4) per year per building. This may or may not be sufficient incentive for the owner or tenant to attempt this level of retrofit.

CONSERVATION STRATEGY R3 - ENERGY CONSERVATION RETROFIT

REQUIREMENT

The total cost of the retrofit cannot be accommodated within the current annual operating and maintenance budget, and capital funding is necessary. In this instance decision making must occur at the corporate level, and this strategy is, therefore, beyond the sole jurisdiction of operating and maintenance personnel.

MEASURES

In addition to those measures in R1 and R2, major adjustments may be made, e.g., re-lamping. In many instances thermal retrofit will be coupled with repair or physical upgrading, and it is important that the energy-related aspects of any cost-benefit trade-off be established.

POTENTIAL SAVINGS

A minimum of 25 per cent in a large facility or 40 per cent in a smaller or older facility. Assuming that all stock were retrofitted to this level, a national saving well in excess of $150,000,000 per year would be realized.

COMMENT

This level of retrofit will be the most difficult to realize. However, using the same figures used in R2, it is evident that a 30 per cent energy saving represents, on average, a saving of about $6,000 per year per building.

CONSERVATION STRATEGY N - ENERGY-CONSERVING DESIGN OF NEW WLIB FACILITIES

REQUIREMENT

An awareness on the part of the designers, developers and owners that a variety of cost-effective* solutions exist, that they can be shown to exist and that, at the very least, operating costs do have some bearing on the viability of the initial investment.

MEASURES

Many of the individual measures are relatively well known within the various segments of the design profession. The principal obstacle to change is the perceived lack of economic advantage for the owner.

POTENTIAL SAVINGS

Steps taken at the design stage could effect considerable energy savings. For example, new buildings constitute between 3 and 4 per cent of the stock each year. With a 'relative saving' of 33 per cent on all new WLIB's, the annual total saving would be:
$(.03 \times .33 \times \$500.10^{6}) = \$5{,}000{,}000$ in 1983, and the equivalent of $40,000,000 in 1990. The cumulative saving would be in the order of $170,000,000 by 1990.

COMMENT

In a 'free-market' economy, this saving may be the most difficult to achieve.

---

* Here cost-effectiveness must take into account any minimum standards (insulation, air leakage, etc.), government incentives, or tax advantages that may exist.

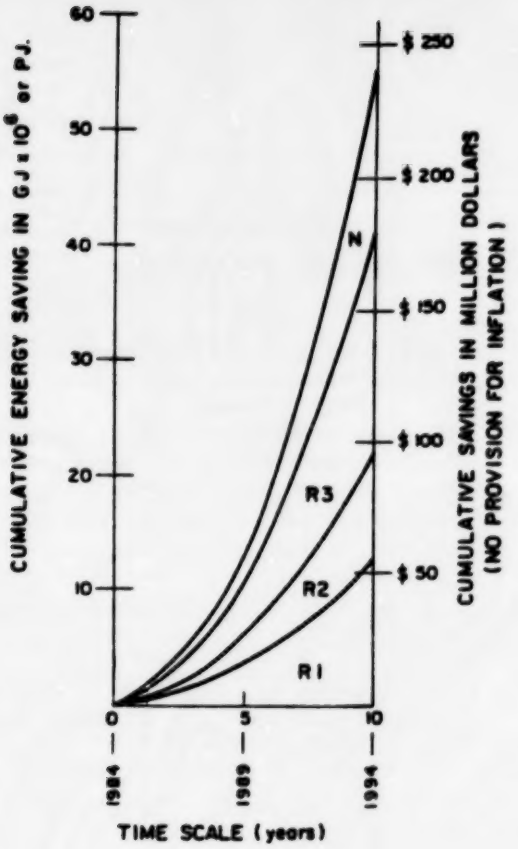
4.3 Conservation Potential

In the previous section the four general energy conservation strategies were identified. Minimum or target energy savings ranging from 5 to 40 per cent were stated. To realistically assess any potential saving, it is necessary to postulate a scenario that assumes a rate of adoption or penetration for each strategy and a time scale for this combination of strategies to take effect.

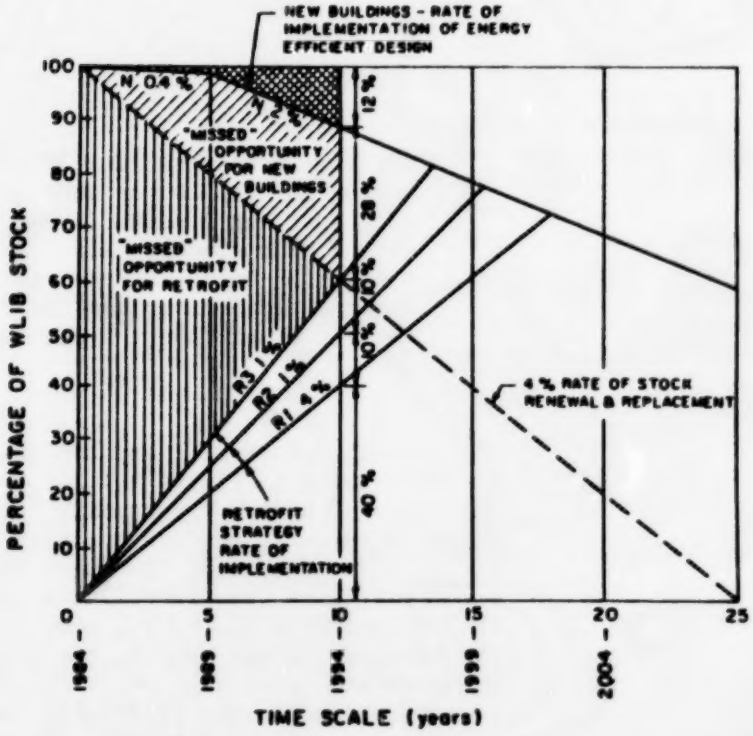
Consider the following scenario where the implementation of:

- Strategy R1 results in a 5 per cent energy saving in 4 per cent of the total WLIB stock each year.
- Strategy R2 results in a 15 per cent energy saving in 1 per cent of the total WLIB stock each year
- Strategy R3 results in a 25 per cent energy saving in 1 per cent of the total WLIB stock of buildings each year
- Strategy N results in a 33 per cent energy saving in only 10 per cent of all new buildings each year for 5 years (about 0.4 per cent of all WLIB stock). After 5 years, due to regulation or incentives, the rate of implementation increases to 50 per cent of the new stock (about 2 per cent of the total stock).

The overall nature of these implementation rates is illustrated in Figure 4.1.A. Also shown is the magnitude of missed opportunity for conservation by means of retrofit and new building design. After 10 years it is evident that most of the original stock will have been retrofitted (40 per cent R1, 10 per cent with R2, 10 per cent with R3). Furthermore, 12 per cent of the stock will be well designed and relatively new. But 28 per cent will be composed of poorly (thermally) designed and relatively new buildings that are in need of thermal retrofit.



B) CUMULATIVE ENERGY SAVINGS



A) STOCK PENETRATION FOR EACH STRATEGY

FIGURE 4.1 : CONSERVATION SCENARIO

The cumulative energy saving in terms of both energy and 1981 dollars is shown in Figure 4.1.B. Evidently this somewhat conservative scenario would realize a total saving of about 55 million GJ of energy (about half one year's total consumption) over a period of ten years. In 1981 dollars, with no provision for inflation or variation in the cost of money, the monetary saving is of the order of 240 million dollars after ten years. It should be noted that after the first year of this scenario, the saving in energy costs would be about $4,000,000.

These figures are indicative of the potential for energy savings in warehouse and light industrial buildings. It remains to be seen how this could be effected and how much effort could be justified in attempting to realize this or other levels of energy conservation.

5. CONCLUSIONS

Our understanding of the potential for energy conservation in the WLIB sector has been enhanced significantly through the work done by and for BEG to date. Specifically, our findings on three key issues have assisted in the definition of the nature and needs of this sector.

- The definition and quantification of the WLIB category has established that in terms of total floor area this category is second only to the residential building category. In Canada there are more than 66,000 warehouses (48,441) and light industrial buildings (17,792), with a total floor area of 98.5 million square metres (more than a billion square feet). New stock is added at the rate of 3 to 4 per cent each year.

- Investigation of the magnitude and nature of the non-process energy consumed by WLIBs has shown that a total of at least 115 million GJ of energy is consumed in Canada at a cost in excess of $540 million each year. About 67 per cent is consumed in Ontario and Quebec, with Ontario using nearly twice as much as Quebec. It is significant that more than 80 per cent of this energy is derived from natural gas; oil contributes only 5 to 6 per cent. Space conditioning and lighting are the main consumers of energy, but in some light industrial buildings make-up air (ventilation) can consume more energy than lighting. Refrigerated storage or freezer warehousing accounts for a significant proportion (17 per cent) of the total energy consumed by WLIBs.

- Implementation of appropriate conservation strategies and the potential for energy conservation in WLIBs involves three strategic steps; namely, the decision to commit resources, the provision of the means or wherewithal and, subsequently, implementation. Four generalized conservation strategies were put forward, and a relatively conservative energy saving scenario was developed. It is evident that over a period of ten years a saving of about 55 million GJ of energy in WLIBs could be realized. In 1981 dollars this saving would be in the order of $240 million.

References 1 to 10 are the reports produced by the Building Engineering Group during the first phase of the BETT program.

(1) Building Category Profile: Warehouse and Light Industrial Buildings

(2) Ventilation, Air Distribution and Air Quality: A State-of-Practice

(3) Sun Related Considerations in the Warehousing and Light Industrial Building Category (unpublished)

(4) Case Study of a New Warehouse

(5) Case Study of an Existing Warehouse

(6) The Potential for Active Solar Heating in Warehousing and Light Industrial Buildings

(7) Air Infiltration in Warehousing and Light Industrial Buildings

(8) Enclosure Considerations for Energy Conservation in Warehousing and Light Industrial Buildings (unpublished)

(9) A Review of Energy Calculation Methods for Warehouses and Light Industrial Buildings

(10) Mechanical and Electrical Systems in Warehousing and Light Industrial Buildings - A State-of-Practice Report (unpublished)

(11) MacDonald R. Desfor G. and Limoff M., Patterns and Levels of Commercial and Industrial Energy Consumption: A Case Study of Metropolitan Toronto. Publication #1 Building Series, Energy, Mines and Resources Canada, Ottawa, 1979

(12) Personal Communication Mr. K. Kent

(13) Burnett, E.F.P., "Making Canadian Housing More Energy Efficient - A Technical Perspective", A report prepared for the Canada Mortgage and Housing Corporation, Ottawa, December, 1980

POOR

QUALITY

ORIGINAL